Airborne Toxic Release/Emergency Response Sub-Component

If a tanker truck carrying hazardous chemicals overturns in a city, could emergency response crews estimate the exposure to vehicles that unwittingly drove through the poisonous cloud? Or, if a terrorist releases a chemical or biological agent in the downtown area, could first responders figure out how the toxic agent spread, where it ended up, and how much was transported away from the scene by moving vehicles? Research now underway at Los Alamos National Laboratory as part of the Urban Security Project might help emergency response personnel answer some of these questions.

The goal of the Airborne Toxic Release/ Emergency Response task was to demonstrate a capability for analyzing emergency response issues resulting from accidental or meditated airborne toxic releases in an urban setting. In the first year of the program, we linked a system of fluid dynamics and vehicle transportation models developed at Los Alamos to study the dispersion of a plume in an urban setting and the resulting exposures to vehicle traffic (see fig. 1).

The HOTMAC prognostic mesoscale model computed three-dimensional meteorological fields over a domain of several hundred kilometers. Zooming in to higher resolution using a nested grid computational mesh, the wind and turbulence fields computed on a 2 km grid size provided boundary conditions for a higher resolution simulation of flow around two 2-d buildings using the GASFLOW computational fluid dynamics code.

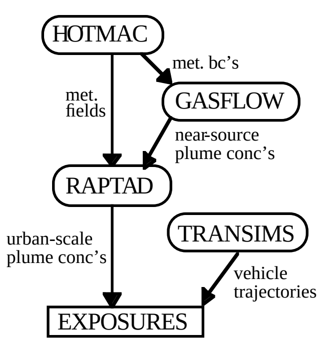

Figure 1. Flowchart showing the links between the mesoscale atmospheric model HOTMAC, the microscale fluid dynamics model GASFLOW, the Lagrangian dispersion model RAPTAD, and the TRANSIMS traffic simulation model.

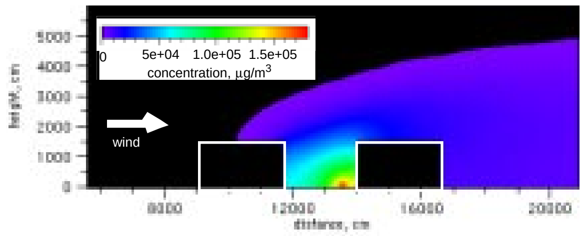

Figure 2. Concentration field computed by the GASFLOW model for a surface release in an urban canyon.

A gas source was located at ground level between the two buildings and the near-source transport and dispersion of the contaminant cloud was simulated at several meter resolution using the GASFLOW model (see fig. 2). Due to recirculation and trapping between the two buildings, concentrations are highly elevated there. The cloud is also lofted very high into the atmosphere downstream of the buildings, a condition of the enhanced turbulent mixing resulting from the building obstructions.

This has an important impact once the plume is passed from the microscale GASFLOW domain to the mesoscale HOTMAC/ RAPTAD domain. As figure 3 illustrates, the pollutant cloud travels farther downwind in a given amount of time when the effects of buildings are explicitly accounted for. Although buildings act to slow down the flow by imparting drag, the lofting of the plume in this particular case results in the cloud being carried by the higher wind speeds aloft. A paper entitled "The effect of microscale urban canyon flow on mesoscale puff dispersion" found in the Appendix gives more details on this portion of the research.

A simulation performed by the TRANSIMS team computed traffic flow for over 250,000 vehicles in North Dallas. TRANSIMS represents a new approach in traffic modeling where the move-

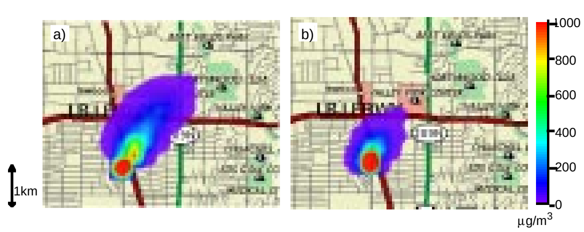

Figure 3. Comparison of GLC fields computed a) with the HOTMAC-RAPTAD and GASFLOW modeling systems and b) with the HOTMAC-RAPTAD modeling system only. This figure shows that explicit modeling of buildings significantly impacts plume transport and dispersion.

ment of individual cars on a second-by-second basis is performed using cellular automata techniques. The interaction of the cars on the microscale results in macroscopic traffic patterns seen in common everyday traffic. Figure 4 depicts the major roadways in the vicinity of the plume, along with the intersection and other nodes in the simulated domain.

Vehicle trajectory and plume concentration data were used to compute exposures to over 36,000 vehicles traveling through the time-varying contaminant cloud. Figure 5 depicts the locations of nodes in the Dallas-Ft. Worth area. The final location and exposure (concentration integrated over time) of each vehicle is shown in fig. 6. The agent is transported by the vehicles over a much larger area than the plume covers. Moreover, the final locations of vehicles with high exposure is not intuitively obvious.

Using a modeling system like this, emergency response personnel could determine the impact zones, the optimal routes for response teams, where casualties might occur, and how the agent is dispersed. The efforts of clean-up crews and medical teams could be enhanced as well with knowledge of the final location and levels of exposure. Further research efforts are underway at LANL to better estimate the impact of multiple buildings on plume transport and

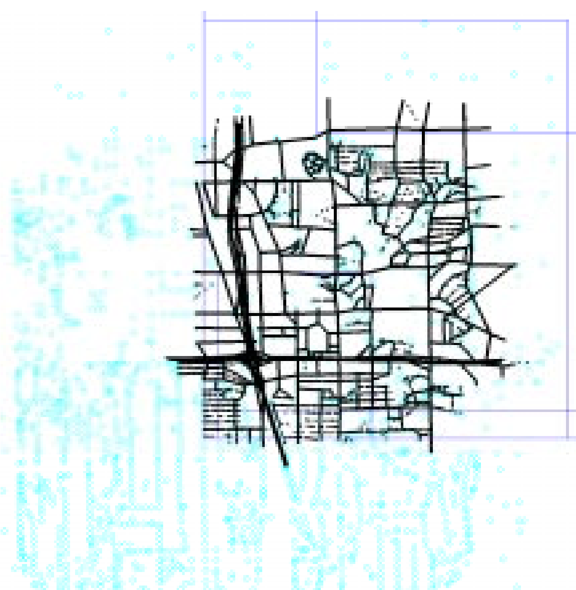

Figure 4. Major roadways impacted by the contaminant cloud. Diamonds represent network nodes and cover the entire active simulation region.

Figure 5. Node locations of the roadway network in the Dallas-Ft. Worth area. The spatial extent of the plume location 10 minutes after release is depicted. The red box demarcates the region of active traffic simulation.

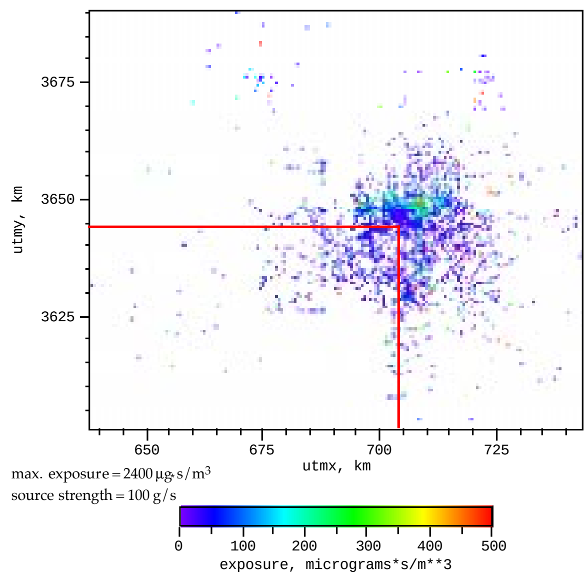

Figure 6. Vehicle exposure as function of final destination. Intersection of red lines denote contaminant plume source location. The dimensions of the roadway network in fig. 5 match those here.

dispersion. Research on transportation simulation continues at LANL, including efforts to perform city-wide simulations with full intermodal routing (automobiles, walking, biking, buses, light rail) and computing synthetic activities during the simulation for the synthetic population.

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Description of Models:

GASFLOW - a three dimensional computational fluid dynamics model used primarily for solving building interior and exterior flow fields. Solves the compressible Navier-Stokes equations using the ICED-ALE finite difference scheme. Turbulence represented by k-ε closure. Resolution of flow fields typically about a meter. Unique features include combustion of flammable gases, chemical reaction mechanisms, entrainment and deposition of aerosols. See Travis et al. (1994) for more details.

HOTMAC (Higher Order Turbulence Model for Atmospheric Circulation) - a prognostic three-dimensional mesoscale atmospheric model used for computing meteorological flow fields in complex terrain. Solves the incompressible hydrostatic geophysical equations using the ADI finite difference scheme. Turbulence represented by the k-l closure. Horizontal resolution typically about 1 kilometer and vertical resolution about 4 meters near the surface and expanding with height. Accounts for landclass variations, urban and forest canopy effects, and has nested grid and data assimilation capabilities. See Yamada and Bunker (1989) for more details.

RAPTAD (Random Particle Transport And Diffusion) - a Lagrangian random-walk puff dispersion model used to compute concentration fields in complex terrain. Uses meteorological fields produced by HOTMAC as input. Thousands of pollutant puffs are released one after another, transported by the mean wind and spread by the turbulent field. Accounts for buoyant plume rise, point, area, and line sources, and can utilize 3-d temperature, wind, and turbulence fields. See Williams and Yamada (1990) for more details.

TRANSIMS (TRANsportation SIMulation System) - a model that simulates traffic flow by following trajectories of multitudes of individual cars. A synthetic population is developed that is statistically similar to the real population in the city of interest and each household is given a daily activities plan (e.g., go from home to work, from work to shopping). On a one second time interval, cars move and interact with each other using cellular automata driving rules. From the simple microscale interactions, complex macroscale traffic behavior develops. For further details see Barrett et al. (1995).

References.

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